Marine Factors in the Production of Salmon: Their Significance to the Pacific Salmon Treaty

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A similar paper describing Canada's perspective has been solicited and is tentatively planned for the next issue (summer 1996) of the Bulletin.

INTRODUCTION

Pacific salmon migratory behavior in the ocean and the critical role of marine residence in salmon production relate to Article III of the Pacific Salmon Treaty (PST). One of the basic objectives of that article, the "equity" principle, provides that each party is "to receive benefits equivalent to the production of salmon originating in its waters." The following international, biological, and economic considerations (1) relate to the Canadian proposition that production of and proprietary rights to salmon are defined solely by spawning location, and (2) form the basis for including marine life stages in the conceptual framework of production employed in the PST. The view developed here is that, for purposes of evaluating fishery equity, salmon production encompasses all aspects of salmon life history.

Production of salmon involves processes that begin with deposition of eggs in freshwater spawning areas and continue throughout their life cycle. After hatching, salmon fry spend from several hours to 2 years (depending on the species) in fresh water and then migrate to marine waters, where they follow species-specific rearing patterns in near-coastal waters and the open ocean. Most salmon growth (generally 99%) occurs during these marine periods.

Salmon life cycles depend on successfully accessing a sequence of habitats, each of which contributes essential elements to survival and growth. Use of these habitats by growing salmon frequently involves sequential residence in Canadian and U.S. waters, and therefore, it is reasonable to propose that those salmon are jointly produced. Furthermore, real costs to both parties are associated with such shared production. Apportioning the economic benefits ultimately generated by these salmon should fairly reflect the relative contributions to production made in each country's waters.

INTERNATIONAL AND LEGAL CONSIDERATIONS

One of the contentious debates during negotiation of the PST centered on salmon production. Canada argued for wording in Article III that would credit each nation for "production of salmon originating in its rivers." However, the accepted wording, "in its waters," reflected that salmon are the product of much more than freshwater birthplace. Taking into account marine elements of complex salmon life cycles seems intuitively essential in determining legitimate national claims to salmon that cross jurisdictions.

Canada has consistently asserted that a nation has the right to harvest salmon spawned in its rivers and other nations do not. In the Canadian view, equity status should be determined by the relative gross values of intercepted salmon, meaning salmon caught in one nation's fisheries that spawned in the other nation's waters. That is, the gross value of salmon intercepted by the nations' fisheries should be compared, equity being achieved only when the value of the respective interceptions is equal.

An alternative, and in our view, more defensible approach holds that *host nations* (i.e., countries that support the growth of salmon spawned in another country) are not simply interceptors of another nation's salmon. Rather, each country in whose waters salmon live and grow contributes essentially to the well-being of those stocks. As Yanagida (1987) observed, host country contributions may be greater than those of the nation with jurisdiction over the spawning grounds. The Canadian position disregards the role of U.S.

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coastal and Exclusive Economic Zone (EEZ) waters in the marine phases of salmon life history.

National rights to salmon based on location of spawning is not mandated in the PST. Neither are such exclusive rights specified in the 1982 United Nations Convention on the Law of the Sea (UNCLOS; Burke 1991) or in other relevant international forums, such as the North Atlantic Salmon Conservation Organization (NASCO; Bubier 1988) or the North Pacific Anadromous Fish Commission (NPAFC). Canada has referred to the "country-of-origin" principle in Article 66 of UNCLOS as supporting its view of rights to anadromous stocks, wherever they migrate. UNCLOS established the authority by which nations may regulate harvest of their indigenously spawned salmon on the high seas. However, in reference to anadromous stocks present in marine waters of another nation, Article 66 does not prescribe limitations on fishing within an EEZ as it does with respect to the high seas but, instead, calls only for cooperation between those countries, presumably in a bilateral forum such as the Pacific Salmon Commission (PSC).

Country-of-origin authority over anadromous species does not extend, by law or by custom, into the waters of another nation's EEZ (Bubier 1988; Burke 1991). This distinction between high seas and waters within national jurisdiction is incorporated in both NASCO and NPAFC and is recognized in U.S. domestic law, specifically provisions regarding anadromous species in the Magnuson Fishery Conservation and Management Act. Under the Magnuson Act, U.S. jurisdiction over fishing on salmon spawned in U.S. territory ceases when those salmon enter the EEZ of another nation. Consequently, international legal considerations and international conventions do not support the concept that a nation has exclusive rights to the value of salmon spawned in its waters that migrate into another nation's waters.

BIOLOGICAL ASPECTS IN SALMON PRODUCTION

Alaska holds that equity considerations must reflect the basic biological and physiological requirements of salmon. The complex events and processes that control growth and survival of immature PST salmon stocks during marine residence include 2 distinct phases: (1) nearshore rearing in the initial year at sea, and (2) subsequent seasons in more offshore conditions.

Nearshore Juvenile Rearing

The behavior of *juvenile* salmon (i.e., those in their first year at sea) upon entering salt water has evolved to optimize growth and survival. As soon as physiologically capable of withstanding full-strength seawater (e.g., LeBrasseur and Parker 1964) and having attained a threshold size (e.g., Koenings et al. 1993), young salmon generally migrate to the northern reaches of the Gulf of Alaska, a region entirely within U.S. waters (Hartt 1980; Hartt and Dell 1986). This behavior pattern is widespread among salmon species and stocks under PST jurisdiction.

Two significant exceptions are recognized. *Ocean-type* chinook salmon *Oncorhynchus tshawytscha* (i.e., chinook salmon that display relatively brief residence in fresh water after hatching, smoltify in the estuarine environment, and remain in the vicinity of their natal rivers for most of their first year) in their second year move quickly to the north where they establish stock-specific ocean ranges in near-coastal waters until maturity (Healey 1983; Healey and Groot 1987; Orsi et al. 1987; Orsi 1988). Some or occasionally most coho salmon *Oncorhynchus kisutch* from the Fraser River, Puget Sound, and Lower Georgia Strait rear in the Strait of Georgia–Strait of Juan de Fuca–Puget Sound area (Healey 1980; Hartt and Dell 1986); the degree of stability of this pattern is not clear.

The massive northward migration of most other juveniles begins each year with southern stocks, which enter salt water first, and proceeds along the coast, more northerly stocks entering throughout the spring (Hartt 1980; Hartt and Dell 1986). The rate of movement can be very rapid, especially for southern stocks. This procession, confined within the boundaries of the Alaska Coastal Current (Cooney 1984), follows the continental shelf within roughly 40 km of the coast and continues around the rim of the Gulf of Alaska throughout the summer and into the autumn months (Hartt and Dell 1986).

Rapid growth is the salmon's best defense against predation during the early marine period (Parker 1971; Hargreaves and LeBrasseur 1985; Whitmus 1985). Juveniles leaving the vicinity of their natal streams and migrating into the ocean may therefore, through natural selection, seek out seasonal habitats that provide preferred forage, low density of predators, and favorable temperature regimes. These critical factors for growth and survival may underlie the large-scale movement into the northern Gulf of Alaska. Specifically:

1. Availability of suitable forage increases many fold as the juveniles proceed north. Forage density is 2 to 3 times greater on the continental shelf, and it increases to roughly 5-fold further north, especially in the highly productive nursery area west of Prince William Sound (Ware and McFarlane 1989).

2. Ocean habitats north of the Queen Charlotte Islands exceed the range of certain known predators, such as Pacific hake *Merluccius productus* and jack mackerel *Trachurus symmetricus*, which can prey heavily on juvenile salmon in the south (Ware and McFarlane 1989). Predation is considered to be the most significant source of mortality for juvenile salmonids in the marine environment (Parker 1965, 1968; Ricker 1976; Hargreaves and LeBrasseur 1985).

3. Water temperatures optimal for growth of juvenile salmon are often exceeded off British Columbia in June and off Southeast Alaska in July and August (French et al. 1976). Waters that are too warm decrease food-conversion efficiency in salmon (Nielson et al. 1985). The observed active migration into temperature conditions that optimize growth increases survival and becomes adaptive (French et al. 1976; Neave et al. 1976).

Survival of salmon juveniles improves with increasing latitude (Hopley 1991; Koenings et al. 1993). Salmon stocks that have ready access to the advantageous marine conditions of the northern and western Gulf of Alaska survive at higher rates, while those that must travel substantial distances to reach this rearing area experience significantly lower survivals. However, the advantage in reaching the Gulf of Alaska nursery apparently justifies the biological cost experienced in route. Additionally, mortality rates sustained by young salmon are reported to decrease to very low levels once they have reached the northern nursery areas (Foerster 1955; Parker 1962; Ricker 1964, 1976). These findings confirm that U.S. coastal waters provide necessary and critical habitat for most salmon stocks of the Pacific Northwest.

A massive volume of juvenile salmon occur in the relatively confined northern Gulf of Alaska (Cooney 1983), making these Alaskan and EEZ waters especially important. The actual volume fluctuates with the strength of wild salmon year classes coastwide and output of salmon enhancement programs in both the United States and Canada. Thus, the carrying capacity of the ocean habitat has been questioned (Cooney 1984; Ware and McFarlane 1989), especially for pink *O. gorbuscha*, chum *O. keta*, and sockeye salmon *O. nerka*, which are the most abundant salmon species and potential competitors for available forage. No definitive answers to the carrying capacity of the ocean habitat or of the Alaska Coastal Current have been developed. However, preliminary calculations regarding the Alaska Coastal Current (Cooney 1984; Hargreaves 1984) place the gross availability of forage species within the range of estimated food requirements for the region's juvenile salmon. Because these estimations were based on regional salmon production that was substantially lower than that observed in more recent years, food availability could become limiting in years with low forage productivity or high juvenile salmon abundance.

Interspecific and intraspecific competition from increased young-of-year salmon abundance may slow salmon growth and decrease survival (Peterman 1978; Salo 1991). However, isolation of such cause-effect relationships in the complex ocean environment, especially when innumerable stocks and species are involved, poses a daunting research problem. Although forage availability may not be limiting, researchers have noted reduced survival associated with increased density of like-aged salmon (Gallagher 1979; Peterman 1978, 1982; Beacham and Starr 1982; S.L. Schroder cited in Salo 1991). It follows that marine survival of young salmon could be depressed by competitive effects, especially when high levels of abundance occur within a geographically confined area.

Offshore Subadult Rearing

Subadult salmon (i.e., postjuveniles until their spawning migration), other than chinook, begin to move into more offshore ocean areas in the early winter of their first year at sea (Godfrey et al. 1975; French et al. 1976; Neave et al. 1976; Takagi et al. 1981). They spread broadly through the northern Pacific Ocean. They do not, however, subsequently maintain an undifferentiated distribution on the high seas. As spring develops, subadults again move north into the Gulf of Alaska and west along the Aleutian Islands, largely within U.S. waters, in species-specific patterns that are repeated annually until maturity.

Pink and coho salmon spend approximately 15–18 months at sea before returning to spawn. Coho salmon, especially in their second spring, feed along the coast before the spawning migration (Godfrey et al. 1975; Sandercock 1991). Their coastal feeding range ordinarily is substantially north and west of their spawning destination. In this period of very active feeding, coho salmon generally double their weight between

June and September (Prakash and Milne 1958; Ricker 1976). Pink salmon stocks covered by the PST generally proceed farther into the northern offshore feeding areas before turning to the south and east in their spawning migration (Takagi et al. 1981; Heard 1991), landfall typically being reached well to the north of each stock's ultimate spawning destination.

Chinook salmon spend substantially greater portions of their life in the ocean, commonly up to 5 years for some stocks. They remain relatively close to the coast throughout their ocean lives (Major et al. 1976; Healey 1991), where each stock appears to maintain a particular range (Healey 1983; Healey and Groot 1987). These chinook stocks spread along the coast to points as far west as the Aleutian Islands and even into the Bering Sea.

Sockeye and chum salmon, in contrast, are primarily planktivores and remain offshore in the rich feeding grounds (French et al. 1976; Neave et al. 1976; Burgner 1991; Salo 1991). During the summer growing season, their ocean ranges as subadults are largely within the EEZ of the U.S. Nearly all North American sockeye and chum stocks appear to congregate within this area (generally west of 145ºW. longitude). They are wholly absent from or only transitory in Canadian waters. Distribution of subadults is closely associated with specific water temperatures, maximum concentration occurring within the 10ºC isotherm. Individuals are detected only rarely in waters warmer than 12ºC (French et al. 1976; Neave et al. 1976). These water temperatures define ideal metabolic conditions for efficient food conversion, maximum efficiency occurring at approximately 10ºC (Straty and Jaenicke 1980).

Growth during ocean rearing appears to be affected by the abundance of competitors, both within and among species that feed on the same prey types. In years of greater total abundance, adult size tends to decrease (Rogers 1980; Takagi et al. 1981; Peterman 1984a), and for some species, the average age at maturity increases (Helle 1979; Beacham and Starr 1982). These observations suggest density-dependent effects on growth of subadult salmon in some years, and substantial numbers of subadult salmon rearing in northern U.S. waters would exacerbate those effects.

ECONOMIC ASPECTS IN SALMON PRODUCTION

Canada regards its costs in producing salmon as investments to be recovered by reaping harvest benefits of those salmon. Those investments include protection of freshwater habitat, enhancement costs, escapement management, and so on. Canada has not acknowledged the U.S. costs sustained when Canadian-spawned salmon occupy U.S. waters. These include 3 types of costs for the U.S.: (1) impacts to its natural resources, (2) fishery management costs, and (3) reduced fishery opportunities on indigenous U.S. stocks. Similar to Canada's view on its costs, the following U.S. costs can be interpreted as U.S. investments in coproduced salmon.

Resource Effects

If forage is limiting, numerous stocks spawned in Canada would compete with Alaskan stocks for available forage while rearing in the Gulf of Alaska. The nature and degree of such competition would undoubtedly vary with the individual species and would be influenced by the annual shifts in primary and secondary production (Ware and McFarlane 1989) and total salmon abundance. Increased density of rearing salmon can slow the rate of growth, apparently through reduction of forage availability (Beacham and Starr 1982; Peterman 1984b). During years of low forage production, competition could be exacerbated. Slower growth could decrease survival, particularly during the early months at sea.

Larger-sized juveniles from Canadian stocks have a competitive advantage over smaller-sized Alaskan juveniles. Migrants from southern (Canadian) waters are larger at a given date due to earlier entry into salt water (Martin 1966; Hartt 1980; Hartt and Dell 1986). This size confers a competitive advantage, both in terms of access to forage and avoidance of predation. For example, juvenile coho salmon demonstrate a preference for smaller pink and chum fry as prey (Parker 1965; Healey 1982; Hargreaves and LeBrasseur 1986), which could increase mortality of the smaller-sized Alaskan juveniles.

Canadian enhancement activities are subsidized by U.S. resources. The introduction of massive numbers of rearing coho, sockeye, and chinook salmon into U.S. waters, or *biological flooding,* could exacerbate competition. As such, Canada's enhancement program builds an economic resource utilizing U.S. raw materials, which can preempt production and harvest of U.S. salmon and produce salmon harvested in Canada that compete with U.S. product in the marketplace.

In the process of foraging in U.S. waters, Canadian-spawned salmon consume species that have economic value to the U.S. For example, Pacific herring *Clupea pallasi* support a large commercial fishery in Southeast Alaska and are well documented as a frequent forage item of both coho and chinook salmon

(Senter 1940; Pritchard and Tester 1944; Reid 1961). In addition, coho salmon are significant predators of juvenile pink and chum salmon and have consumed 50% or more of some localized prey populations (Parker 1968, 1971; Bax 1983; Hargreaves and LeBrasseur 1986). Similarly, chinook salmon are known to consume other salmon juveniles (Karpenko 1982; Robinson et al. 1982). Canadian-spawned coho salmon enter inner coastal waters in Alaska where pink and chum salmon juveniles are concentrated (Hartt and Dell 1986), and Canadian-spawned chinook salmon also frequent the coastal waters of Alaska (Orsi et al. 1987; Orsi 1988).

Fishery Management Costs

Extensive and expensive stock-separation research and monitoring has been requisite to managing Alaskan stocks for sustained yield. The presence of Canadian salmon complicates this process and has imposed cost factors both in direct research expenditures and professional time commitments.

Inseason run-strength assessment of stocks in traditional Alaskan fisheries has necessarily included the development and application of methods to detect run size of specific Canadian stocks (e.g., Nass or Skeena sockeye salmon). Such methods are expensive but necessary if those stocks are to be adequately conserved.

Development of the capacity to distinguish enhanced from wild components in salmon runs is necessary. With the mandate in Alaska to manage for wild stock sustained yield, large influxes of salmon from Canadian enhancement activities impose a costly and substantial wild/hatchery stock identification problem for U.S. fishery management. For fisheries managed on catch-effort data, greater proportions of enhanced stocks create a greater need for accurate estimation of the hatchery component in a fishery in order to avoid shortfalls in wild stock escapements (Wilbur and Frohne 1989).

Effects on Fishing Opportunities

When conservation actions are taken to reduce harvests of Canadian stocks, or when allocation guidelines are reached in bilaterally agreed fishing regimes, there can be loss of fishery access to intermingled U.S. salmon, some of which will not be recovered in alternative fisheries.

This loss can be very significant, especially when Canadian enhancement activities significantly increase the abundance of those stocks and that, in turn, causes allocation ceilings to be attained which prematurely truncates fisheries on domestic stocks. This *fishery flooding* has been a consistent problem in the Southeast Alaska pink salmon fishery, in which Canada's enhanced salmon are taken as incidental harvest. Likewise, Canada's enhanced chinook salmon have increased as a proportion in Southeast Alaska chinook fisheries so that those traditional fisheries have been foreshortened through prohibiting chinook retention.

Management actions designed to achieve either conservation or allocation objectives with respect to Canadian salmon also lead to disruptions in other Alaskan fisheries. Resulting fleet movements increase the economic inefficiency of fisheries. Closure of one fishery can lead to loss of fish quality in subsequent fisheries, and thus value. This redistribution of harvests and disruption of established allocations in normally concurrent fisheries can economically damage dependent local economies.

CHANGING CIRCUMSTANCES

While Canada's focus on balancing interceptions and promoting exclusive rights to Canadian-spawned salmon has been maintained consistently for more than 25 years, the United States has never agreed with that view (Yanagida 1987; letter from U.S. Ambassador D. A. Colson to Canadian Ambassador Y. Fortier dated February 3, 1994). The consistency of the Canadian view, however, is problematic because circumstances have changed since the early 1970s. Canada's perspective certainly was more understandable when ocean waters beyond 12 miles (and previously 3 miles) from the coast were considered to be high seas not under the direct jurisdiction of any nation. But during the intervening years 2 major changes occurred:

1. National jurisdictions were extended to 200 miles offshore, expanding, especially for the U.S., national authority over far more of the natural ocean range of North American salmon.

2. Use of U.S. waters by many salmon stocks was not well known until recently, but biologists now have far greater understanding of the ocean life of salmon, particularly stock distribution within the U.S. EEZ and the physical and physiological factors governing salmon distribution and survival at sea.

Canada's position regarding fishery equity has not incorporated these significant developments, and their reluctance to do so has created a challenging climate for negotiating interjurisdictional salmon fishery issues. That climate in 1994 precipitated Canadian government implementation of a policy to maximize harvests of U.S. stocks in Canada (Tobin 1994), which ironically led to overfishing Canadian stocks (e.g., FRSPRB 1995). These events further polarized the treaty process, which was founded on the principle of optimizing salmon production bilaterally. Concurrently, the influence of professional fishery managers and scientists in salmon fishery decision-making was greatly reduced. This unfortunately, has neither benefited the resource nor served the goal of attaining equity.

CONCLUDING OBSERVATIONS

International law fails to support Canada's proprietary view of salmon originating in its rivers but instead calls for bilateral cooperation. Accepting shared production may offer the only practical means of achieving equity reflecting both countries' contributions.

Available literature pertaining to the ocean phases of salmon indicates that salmon spawned in Canada spend extended and critical periods of their life cycles in U.S. waters off Alaska. Those marine areas are conducive to salmon growth and survival by providing abundant food, limited predation, and optimal temperatures. In our view, the documented biological behavior of PST populations validates that salmon production is derived from both countries' waters.

From the economic perspective, numerous significant expenses are borne by the U.S. as Canadian-spawned salmon rear in U.S. waters. These costs represent investments by the United States in salmon spawned in Canada. When biological resources are limiting, and even in circumstances where they are not, the Alaskan and U.S. waters contribute significantly to Canadian-spawned salmon production. Contributions or investments by both countries are necessary to their production. Consequently, it is reasonable to recognize both countries' production costs for jointly produced salmon.

Finally, a proprietary view of indigenously spawned salmon raised in another country's waters impedes improving the status of salmon stocks because it fails to develop incentives that would promote mutual fishery interests. Those incentives for the host or rearing country highlight the contrast between the Canadian perspective on equity and the alternative perspective, which accepts joint responsibility for salmon production.

Negative Incentives

Treating national interests in coproduced salmon stocks on an all-or-none basis creates disincentives for the host country. Salmon stocks that rear, but do not spawn, in its waters bring the burden of extensive costs without compensating benefits. With high abundance, biological effects on the host's resources can be heightened by reduced indigenous-stock production and traditional fishery patterns can be disrupted. When stocks are in low abundance, requiring specific conservation actions, the host has little motivation to assist in conservation not tied directly to the status of its own stocks. With no vested interest in nonindigenous salmon, the host country will seek to protect its own interests. This may be manifested in passive or even active suppression of the nonindigenous salmon.

Positive Incentives

Quite different incentives surround salmon stocks that are acknowledged by the nations as a jointly produced resource. Recognition of legitimate interest in rearing salmon by the host nation establishes the foundation for optimizing production. Vested in the rewards of proportionately increased harvests from increased abundance, active participation in stock conservation and enhancement actions are in the interests of the host country. Although vigorous negotiations will still occur in seeking to establish harvest shares, anticipation of reasonable returns from the investments of both the country of origin and host nation provides a significant key to the long-term health of jointly produced salmon populations.

Return to Science

Consideration of marine factors in salmon production provides a basis for assessing practical policy issues in the PST and helps clarify outcomes from conflicting policy orientations for the salmon stocks. A production-based approach to equity would hopefully foster a more objective basis for decisions that impact salmon and their users. However, given the stalemated PST political arena, real accommodations and solutions may have to be initiated, not just implemented, by the fishery managers and scientists who best understand the salmon resource, who are committed to sound stewardship, and who possess the knowledge to lead their nations to accepting the shared responsibilities and benefits of jointly producing salmon.

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